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Indicators of Acute Pain and Fly Avoidance Behaviors in Holstein Calves Following Tail-docking

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ABSTRACT

Previous work showed that the banding process of docking minimally affected mature cows' behavior and physiology, but cutting off the necrotic tail increased haptoglobin. Additionally the docked cows had more flies on the rear legs and exhibited more fly avoidance behaviors. Because many producers dock young calves while they are in hutches where fly problems are more pronounced, we investigated changes in behavior and physiology of young calves following docking by banding. Twenty calves (3 to 5 wk of age) were assigned to a docked or control group, at each of two locations (Indiana and Wisconsin). After applying a band to dock the tail, calves were tested every 15 min for sensitivity to heat below the band at the Indiana location. Calf behavior was recorded for 2 h postbanding and analyzed continuously for that period. After 3 wk, tails were removed and then 1 wk later, fly counts and fly avoidance behaviors were observed at both locations. Tails were sensitive to heat below the banding site, for 60 to 120 min postbanding (mean 87 min). Banded calves were more active than control calves during the 2 h following banding. Percentage of time spent lying was greater for control calves, and the percentage of time spent walking was greater for docked than control calves. More importantly, movements of the head to touch the tail were increased for banded calves (eight-fold more movements). Fly avoidance behaviors directed toward the rear of the calf were evident at noon or in the afternoon. Ear twitches were more frequent for the docked calves and less frequent in the morning for all calves. Licking was more frequent for the docked calves at 1200 and 1600 h. Tail swings were most frequent at 1200 and more frequent for control calves. Two acute phase proteins, haptoglobin and α_1 acid-glycoprotein, were not different at any time. In this study, calves that were banded at 3-wk-of-age showed behaviors indicative of discomfort for 2 h, were attacked by more flies, and showed increased fly avoidance behaviors when docked.
(**Key words:** pain, flies, behavior)

INTRODUCTION

Tail docking of dairy cattle continues to be an animal well-being question in the United States and Canada. Rationales for docking include improvement of udder cleanliness and control of debris in holding areas and milking parlors. However at this time, data show only legs and side areas are affected by tail docking (Wilson, 1972; Eicher et al., 2001), while udder cleanliness remains unaffected (Eicher et al., 2001; Tucker et al., 2001). Additionally, several studies have shown that banding the tails, a method to dock tails of mature cattle, induces few detectible behavioral or physiological indicators of pain (Petrie et al., 1996; Eicher et al., 2000; Tom et al., 2001). Banding, followed by removal of the necrotic tail after 7 to 14 d, is a typical method to dock mature cattle, and banding at less than 3 wk-of-age without removal of the necrotic tail until 6 wk-of-age is a commonly used method to dock the tails of young calves. Besides the concern about the acute pain associated with the procedure of tail docking, the ability of the heifers to combat flies is a well-being issue. Fly numbers and some fly avoidance behaviors increased on docked cows in tie-stalls (Eicher et al., 2001) and on pastures (Phipps et al., 1995).

The stable fly (Stomoxys *calcitrans* L.) is one of the most common types of disruptive flies in the United States (Dougherty et al., 1995). These flies are the most bothersome when they are biting, which occurs when flies feed as temperatures become warm. The feeding lasts from 2 to 5 min, then the flies remain on the animal to either rest or seek a new feeding station. Cattle attempt to escape this annoyance by taking flight, stomping, kicking their trunk, tail swishing, skin twitching, and head or ear movements. Flies become an economic liability because of disruption and alterations of eating patterns and increased energy expendi-

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ture in avoidance behaviors. Biting flies have been linked to disrupted grazing, slower growth (Campbell and Berry, 1989), reduced milk production and weight gain, and increased stress (Jonsson and Mayer, 1999). Campbell and Berry (1989) established an economic threshold of two stable flies per foreleg. New Zealand studies showed that at low (zero) fly numbers in the morning, there were no differences in frequencies of fly-avoidance behaviors (such as stomping, ear twitching, and tail swings) between intact and docked cows. However, at later times of the day (1200 and 1500 h) fly counts increased (more than 20 per side per 6 min), and docked cows had more avoidance behaviors that relieved the rear of the cow from flies than did the control cows (Phipps et al., 1995). Fly numbers were greater on docked cows (Wilson, 1972; Matthews et al., 1995), and fly counts were greater on rear legs of cows with trimmed switches and docked cows (Matthews et al., 1995; Eicher et al., 2001). Concurrent data showed an increase in fly avoidance behaviors in docked cows. Interestingly, cows in New Zealand that had switches trimmed but not docked were similar to controls for tail flicks, but similar to docked cows for foot stomps. All of these studies were conducted on mature animals in free-stalls, tie-stalls, or on pasture setting. Calf hutches are a good breeding ground for flies causing young calves to be more prone to fly pestering than mature animals housed in most confined housing systems or on pastures. No studies to date have addressed the impact of tail docking on calves while housed in hutches.

Cortisol is released in response to both tail docking and fly irritants. Cortisol briefly increased after tail docking in neonatal calves (Tom et al., 2001). With increased fly bites, cortisol concentrations and heart and respiration rates increased in mature animals (Schwinghammer et al., 1987). Acute phase proteins are proteins released from the liver following pathogenic infections, tissue damage, and to some stressors such as withholding of feed. Since increased plasma cortisol can exacerbate concentrations and duration of acute phase proteins (Baumann and Gauldie, 1994; Gabay et al., 1995), it follows that plasma acute phase proteins may increase with fly bites, which may be more numerous following tail docking. Previous studies have shown increased haptoglobin in response to removal of the tail of mature dairy cattle (Eicher et al., 2000). Some calf acute phase proteins are greatest at birth and decrease over time to near the concentrations of nonstressed mature cattle by 4 wk-of-age (α_1-acid glycoprotein, Eicher, unpublished data), but haptoglobin begins and remains at nondetectable concentrations (Alsemgeest et al., 1993). Besides the immune system of the neonatal calf that is still developing, neurological mechanisms may still be developing as in other species.

Recent evidence shows that for procedures considered painful, some neurological maturation is beneficial (Narsinghani et al., 2000). Some pain damping mechanisms are not fully developed in fetus and neonates; including diffuse noxious inhibitory controls (Ren et al., 1997; Boucher et al., 1998), delayed maturation of interneurons, or the excitory role of neurotransmitters (Bicknell and Beal, 1984; Wang et al., 1994). But the behavioral indicators of pain have not been assessed for young dairy cattle in response to tail docking.

Our objectives in this study were to determine 1) behavioral indicators of acute pain after tail banding and 2) fly avoidance behaviors and fly counts on docked and intact Holstein heifer calves.

MATERIALS AND METHODS

Animals and Experimental Design

Calves from the USDA-ARS Forage Research Center, Prairie du Sac, WI (n = 10 per treatment) and from the Purdue Dairy Teaching and Research Center herd (n = 10 per treatment) were blocked by birth date and randomly assigned to docked or nondocked treatments at each site. Each block included two calves, one of each treatment. Blocks of calves were placed in adjoining hutches to control for placement effects. Hutches were placed within 62 cm of each other to allow for video viewing of two hutches with one camera. All heifer calves were born between mid-May and mid-July and housed in outdoor polyethylene hutches (2.18 × 0.97 m) with fencing (approximately 1.5 × 0.97 m) at both facilities. At 3 wk-of-age, one small band (castration band) was applied to the tails of the docked group about 45 cm below the vulva, with care taken to place the band between two vertebrae. Three weeks after banding, any necrotic tails that were still attached were removed by cutting.

Maintenance behaviors (Table 1) were observed for 2 h postbanding in 72 h mode (1.2 s per frame) of a time-lapse video recorder (Panasonic AG-6540, Mipitas, CA) at the Purdue location only (n = 10 per treatment). A BP70 Panasonic camera (Mipitas, CA, outfitted with a wide-angle lens) was housed in a protective weather resistant cover, mounted on a tripod at approximately 71 cm high, and placed 2 m from the front of the calf hutch. Two hutches were viewed with one camera. These behaviors were analyzed by 5 min instantaneous scan sampling (Noldus Observer, Wagegingen, Norway).

Calves' blood was sampled by jugular venipuncture (10 ml) prior to banding and 72 h postbanding, and 1 wk postdocking for Purdue calves (n = 10 per treat-

Table 1. Maintenance, fly avoidance, and pain indicating behaviors of dairy calves banded at 3 wk-of-age. Maintenance and pain indicating behaviors were observed immediately after banding. Fly avoidance behaviors were observed 4 wk after banding (7 wk-of-age)

Maintenance Behaviors	Definition
Standing	Supporting all body weight on four feet
Walking	Forward movement at any rate (includes running)
Lying	Lateral or sternal recumbency
Eating	Nose inside of feed bucket
Drinking	Nose inside of water bucket
Fly Avoidance Behaviors	
Foot Stomping	Raising and lowering of a foot in one spot
Ear Twitch	Rapid movement of ears
Skin Twitching	Skin rippling
Tail Swing	Movement of tail greater than 45° from vertical
Pain Indicating Behaviors	
Head to Tail	Movement of head to touch tail, that was not to dislodge flies or to groom

ment). Blood was centrifuged at 700 × g to obtain plasma that was frozen at –80°C. Plasma samples were used to determine the concentration of two acute phase proteins (haptoglobin and α_1 acid-glycoprotein). Radial immunodiffusion assays were used to determine haptoglobin and α_1 acid-glycoprotein concentrations (Saikin Kagaku Institute Co., Sendai, Japan).

Tests and Assays

The haptoglobin agar gel plates each were loaded with two standards, 25 and 750 μg/ml and eight test samples per plate using standards, L-cysteine reducing reagent, and solvent provided (Morimatsu et al., 1992). The α_1 acid-glycoprotein only required the addition of 5 μl of standard (50 and 1500 μg/ml) or sample per well in a 10 well plate. Previous work in our laboratory, established a coefficient of variation that corresponded to the kit description (< 4%). We have also validated the haptoglobin and α_1 acid-glycoprotein kits for effect of serum compared to plasma, and fresh compared to frozen samples.

In the Purdue herd, a heat sensitivity test (Zenor, 1997; Fender et al., 2000) was administered to control and banded calves (n = 10 per treatment). The heat sensitivity test was performed on the tail end at 15 min intervals for two h postbanding. Heat sensitivity testing began by clipping the lower 15 cm of control and docked calves' tails a day prior to the testing. Water was heated to 60 ± 2.5°C. The heated water was taken to the hutch and the test performed in an insulated cooler. This resulted in less than 1°C drop in temperature during the testing. The shaved 15 cm of the calf's tail was inserted into the water. The time it took the calf to move the tail was recorded if less than 30 s. As in Fender et al. (2000), timing was stopped and the tail removed from the water at 30 s. When two successive tests resulted in the researcher removing the tail at 30 s, the test was discontinued for that calf. The time that the calf first left the tail in the heated water for 30 s to meet the criteria for discontinued testing was recorded, indicating no sensitivity to heat in the tail below the banding site. All testing was discontinued at 120 min postbanding, the time at which none of the control calves but all banded calves had met the criteria.

Fly Counts and Fly Avoidance Behaviors

Beginning in July (fly season), the control and docked calves in both herds were observed for fly avoidance behaviors for a 1-h time period at 0800, 1200, and 1600 using 5 min focal animal sampling on 3 consecutive d. Feeding occurred after the observation period. Flies were counted the hour preceding the behavior observations.

Fly counting procedures: calves were marked at the beginning of the stifle on the back leg and at the joint at the joining of the front leg to the body. Calves were brought to a standing position, and fly counts began after 30 s. Each leg was counted for 2 min, counting two legs simultaneously (McNeal and Campbell, 1981). An average (number per leg) was calculated for the front legs, back legs, and a total.

Behaviors (Table 1) were defined and calves were observed for fly avoidance behaviors. Fly avoidance behaviors were recorded with direct observation by interval time sampling. One focal calf was observed continuously for 5 min, then the next calf was observed for 5 min, until all calves in that block had been observed once between 0800 to 0900, 1200 to 1300, and 1600 to 1700 h. This was repeated for 3 consecutive d. The mean of the 3 d was used as the response of each calf for each of the 0800, 1200, or 1600 h observation.

All animal care was within the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (1999), and animal use was ap-

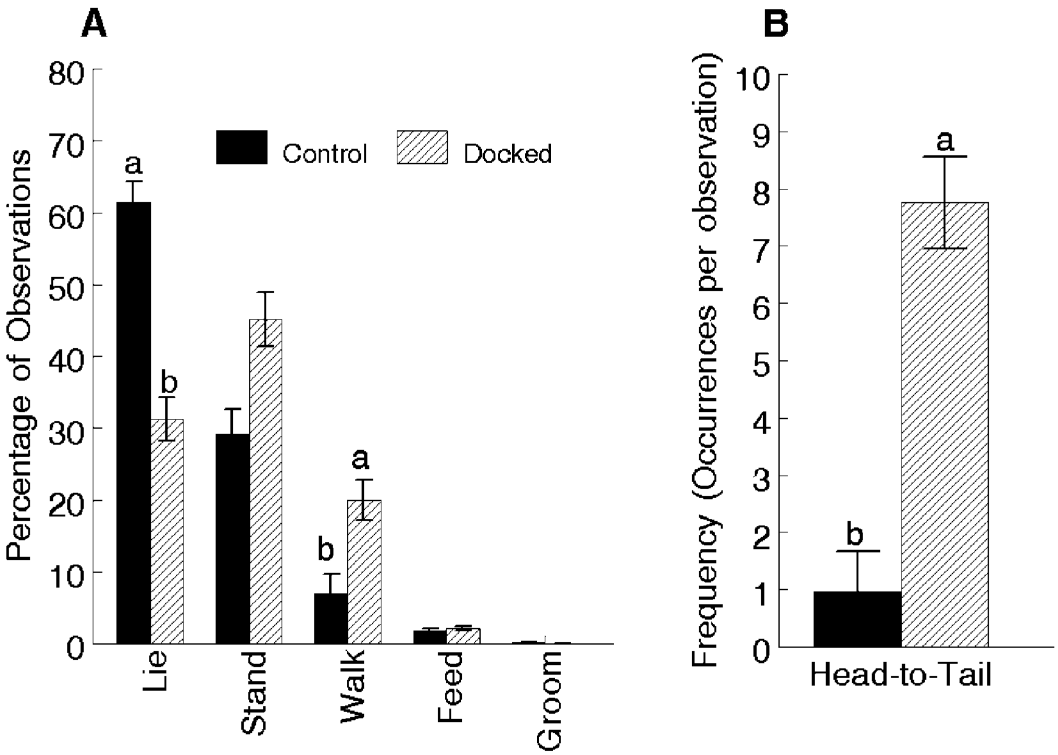

Figure 1. Graph (A), maintenance behaviors and (B) head-to-tail pain indicating movements (not grooming or fly-avoidance) during a 2 h post-banding observation period for banded and control calves (n = 10 per treatment). [ab]Means ± SE within a behavior with different superscripts differ ($P < 0.05$).

proved by the Purdue Animal Care and Use Committee and the University of Wisconsin Animal Care and Use Committee.

Statistical Methods

The Mixed model program of SAS (SAS, 2000; Littell et al., 1996) was used to analyze data as a repeated measures design (compound symmetry and ante-dependency structure used as appropriate for each variable). The fixed effect was treatment (docked or intact) and the random effect was block. Behavior data was normalized using a square root transformation.

RESULTS

Heat Sensitivity Test

By 120 min, all of the docked calves (n = 10) had met the criteria for leaving their tail in the water for 30 s for two consecutive trials ($P < 0.05$), but the control calves (n = 10) all removed their tails from the heated water before 30 s., indicating no decreased sensitivity to the heated water.

Behavior at Banding

Behaviors of docked calves were different than for control calves following banding (Figure 1). Lying decreased ($P < 0.05$; 62.5 and 31.2 mean percentage of observations) and walking (or running) was greater ($P < 0.05$, 7.0 and 20.0 mean percentage of observations) for the banded calves in the 2 h observation period following banding. The percentage of observations with standing was not different ($P > 0.05$) between control (29.1) and banded (45.1) calves. Feeding and grooming, both of which occurred infrequently, were not different between the treatments. Mean percentage of observations were 1.9 and 2.1 for feeding, and 0.1 and 0 for grooming, for control and banded calves, respectively. The specific pain indicator movement, the head-to-tail movement, differed between treated and control calves ($P < 0.05$) being almost eight times more frequent in the banded calves (0.97 and 7.76 occurrences per observation). Seventy five percent of the calves in the study (n = 40) lost their tails without cutting by 3 wk post-banding, leaving four calves at the Indiana location that needed cutting and six at the Wisconsin site.

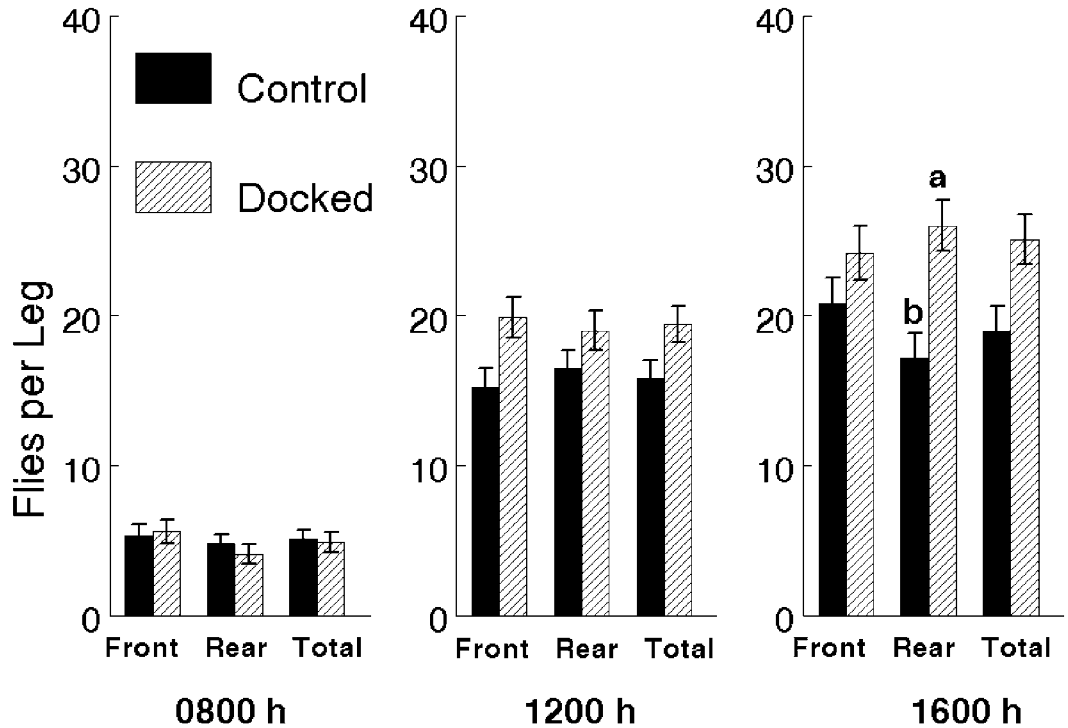

Figure 2. Mean fly counts per leg for front, rear, and all legs at 0800, 1200, and 1600 h. (n = 20 per treatment). Time effect was significant ($P < 0.01$). [ab]Means ± SE within a time and front, rear, or total leg descriptors with different superscripts differ ($P < 0.05$).

Fly Counts

Fly counts (Figure 2) were numerous, particularly by the afternoon (1200 and 1600 h observations) for all calves. The fly counts more than doubled from 0800 to 1200 h and continued to increase by 1600 h ($P < 0.01$). Only at 1600 h were fly counts on the rear legs (but not the front legs) of docked calves greater than the fly counts of the control calves' rear legs ($P < 0.05$). Fly count per leg during the observation period at 0800 h for control and docked calves respectively, were 5.3 and 5.6 per front leg, 4.9 and 4.1 per rear leg, and 5.1 and 4.9 per leg for all four legs. During the 1200 h observation, mean fly counts per leg were 15.2 and 19.9 per front leg, 16.5 and 19.0 per rear leg, and 15.8 and 19.4 per leg for all four legs of control and docked calves, respectively. At the 1600 h observation the fly counts were 20.8 and 24.2 per front leg, 17.2 and 26.0 per rear leg, and 19.0 and 25.1 per leg for all four legs of control and docked calves, respectively.

Fly Avoidance Behaviors

Time of observation (0800, 1200, or 1600) and some treatment effects were significant ($P < 0.05$) for fly avoidance behaviors (Table 2). Ear twitching was more frequent in the docked calves at the 0800 and 1200 h observations ($P < 0.05$). Ear twitching more than doubled from the 0800 to both the 1200 and 1600 h observation ($P < 0.05$) for both the docked and control calves. Tail swings were more frequent for control calves at the 1200 and 1600 h observation ($P < 0.05$). A time of day effect ($P < 0.05$), caused by increased frequency of tail swings from 0800 to 1200 h and a decrease in frequency from 1200 to 1600 h was detected for both control and docked calves. Licking, although infrequent, was most frequent ($P < 0.05$) for the tail-docked calves at 1200 h and tended to be more frequent at 1600 h ($P < 0.10$). Foot stomps and the skin twitching were not significantly different at any time point, nor were the frequencies affected by time of day.

Acute Phase Proteins

No treatment effects ($P > 0.05$; Figure 3) were observed for α_1-acid glycoprotein (383 and 395 before treatments, 367 and 406 at 72 h postbanding, and 272 and 320 at 4 wk postbanding for control and docked calves, respectively) and haptoglobin (31, and 0 before treatments, 0 and 11.1 at 72 h postbanding, and 0 for both at 4 wk postbanding for control and docked calves, respectively). Haptoglobin and α_1-acid glycoprotein concentrations were within normal ranges and none of the

Table 2. Fly avoidance behaviors of control and docked calves at approximately 7 wk-of-age (n = 20 per treatment). Mean frequency per 5 min ± SE. Treatment, Observation Time Period (Time), and Interactions are significant at $P < 0.05$. NS = no significant time or treatment effect

		Control	SE	Docked	SE	Main Effects
		(frequency per 5 min. observation)				
Lick						Treatment ($P < 0.05$)
	0800	3.5	0.30	1.8	0.32	
	1200	2.0	0.34	3.7	0.36	
	1600	2.3	0.39	3.9	0.41	
Foot stomp						NS
	0800	11.2	2.5	11.8	2.5	
	1200	19.7	4.0	23.1	3.6	
	1600	18.8	3.0	28.2	3.7	
Paniculus Reflex						NS
	0800	21.2	3.4	19.5	3.4	
	1200	27.3	3.0	20.9	3.2	
	1600	22.3	2.8	23.6	3.0	
Ear twitch						Time ($P < 0.05$) and
	0800	3.3	1.4	11.7	1.4	Treatment ($P < 0.05$)
	1200	20.6	2.6	35	2.7	
	1600	20.1	3.5	25.3	3.6	
Tail swing						Time ($P < 0.05$) and
	0800	32.0	4.2	21.8	4.2	Treatment ($P < 0.05$)
	1200	82.4	6.9	46.4	7.3	
	1600	48.2	3.6	36.3	3.8	
Total	0800	71.2	9.4	66.7	9.4	
	1200	152.0	9.9	129.0	10.3	
	1600	102.8	8.7	102.8	9.2	

haptoglobin concentrations reached the concentration that is considered to be a response to a stressor (200 μg/ml) in mature cattle.

DISCUSSION

Behavior after Banding

The behavior of calves after banding was in stark contrast to a total lack of behavioral response in mature cattle in previous work (Eicher et al., 2000). An increase in agitation was evidenced by increased moving, decreased lying, and the head-to-tail movement that was specific for banded calves. Calves in another study also increased tail grooming following rubber ring application (Tom et al., 2001). These researchers saw only a trend ($P < 0.08$) for shorter duration of standing and lying, but higher frequencies of standing and lying. This supports the increased movement and general restlessness that we observed.

The heat sensitivity test showed that the tails of docked calves were insensitive 2 h after banding. Five of the banded calves (half of those tested) were insensitive to hot water at 75 min postbanding and the other five were sensitive to the hot water until 105 min postbanding. Therefore pain experienced by the calves after that 2 h period postbanding, must be originating proximal to the banding site. Tom et al., (2001) observed cortisol increased after banding at 1 h postbanding, but not at 30 min postbanding or at any of their time points after 120 min postbanding. This suggests that a moderate acute pain is experienced for about 1 h after the initial cessation of feeling in the tail. Our data only reflect the loss of sensitivity below the banding site. The tail that is above the band may become more sensitive to stimulus as inflammation and swelling occurs. Wilson (1972) noted that mature cows, exhibited swelling at the banding site at 6 h postbanding, increased tail movement 6 h postbanding, and decreased tail movement from those of control cows by 24 and 48 h postbanding. However, our data did not encompass alterations in behavior or sensitivity that develop after the initial 2 h postbanding. Other painful management procedures result in greater increases in cortisol and behavioral indicators of pain. For example, dehorning causes a much greater cortisol increase which lasts for a longer period of time (Sylvester et al., 1998), and increased vocalization is a significant behavioral indicator of pain (Watts and Stookey, 1999). Studies of 4 to 6-wk-old calves demonstrated anesthetic was useful to reduce pain during dehorning. Decreased head and leg movements, plasma cortisol, and duration of increased heart rates were used as indicators of pain reduction (Grondahl-Nielsen et al., 1999). The area around the horn bud of newborn to 3 to 4 mo-old calves was well innervated regardless of age (Taschke and Folsch, 1997).

In other species, pain control mechanisms are still developing in the neonate (Narsinghani et al., 2000).

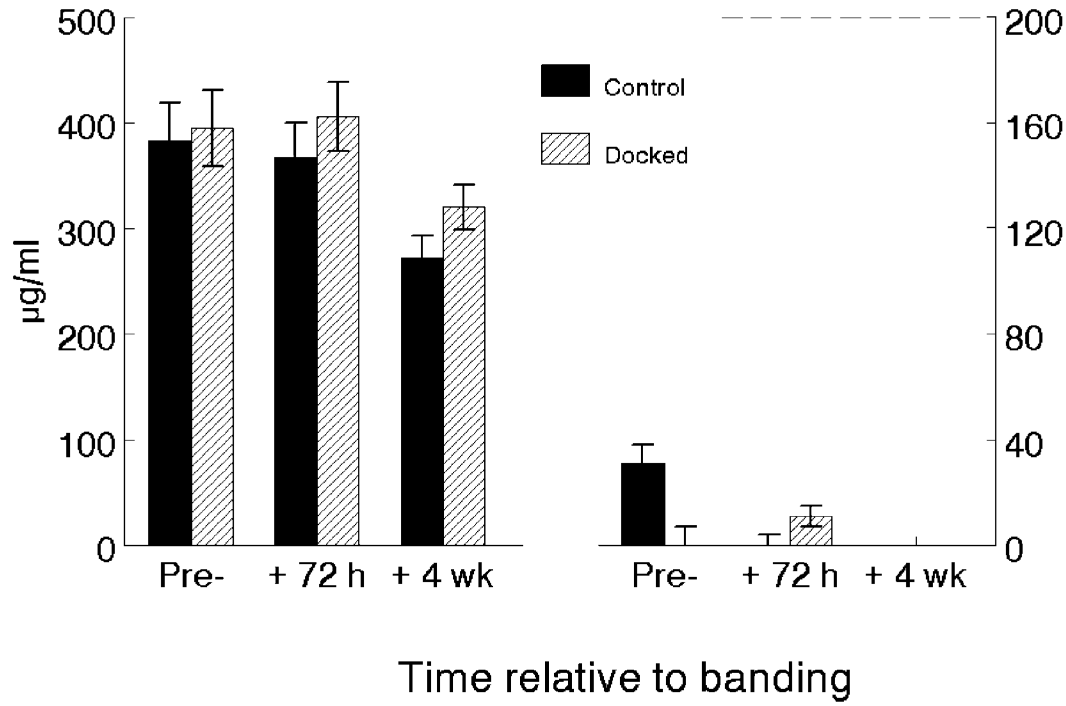

Figure 3. Two acute phase protein responses (μg/ml), haptoglobin and α_1 acid-glycoprotein , of banded and control calves (n = 10 per treatment) . [ab]Means ± SE. No significant differences between treatments were detected ($P > 0.05$). Data for α_1-acid glycoprotein correspond to left Y-axis and haptoglobin correspond to right Y-axis. Dotted line marks the upper normal concentration for haptoglobin.

Specific pain behaviors increase and nonspecific behaviors decrease with advancing neonatal age (Guy and Abbott, 1992). Additionally, mechanisms such as diffuse noxious inhibitory controls follow a rostrocaudal pattern, resulting in higher pain threshold in the forelimbs compared to the hind limbs (Ren et al., 1997). The greater sensitivity of neonates to noxious stimuli and the rostrocaudal pattern of some of the inhibitory controls, may explain the differences in calves and cows responses to tail banding. However, at this time, no published studies are available on the development of pain damping mechanisms in neonatal cattle.

Acute Phase Protein Response

Acute phase proteins are released from the liver in response to cytokine stimulus (Interleukin-1 or -6) and cortisol enhances that response. Infections or tissue damage are two conditions that lead to the release of acute phase proteins. Because of the tissue damage that occurs during banding, acute phase protein release may occur as the tails became necrotic over the 3 wk before the tails were removed. However, acute phase protein concentrations were not greater in the docked calves after banding or after the removal of the necrotic tail. In contrast, this was not true in mature heifer cattle (Eicher et al., 2000). Haptoglobin increased slightly near the end of 1 wk after banding and then concentrations increased dramatically after cutting off the necrotic tail. In the present study, tails were not removed until 3 wk postbanding and most had fallen off by 3 wk postbanding with no further intervention. The difference in acute phase protein response between neonatal and mature heifers may have been caused by sample timing (our sampling time points were based on mature cattle acute phase protein responses to the tissue damage caused by banding and cutting off of the tail), less tissue that is becoming necrotic (calf tails have a much smaller circumference), or removal of the tail before all of it was necrotic in the mature heifers (cows' tails were removed at 1 wk postbanding compared to 3 wk postbanding in the young calf).

Fly Counts and Fly Avoidance Behaviors

Both fly avoidance behaviors and fly counts required direct, live observations. The size of the fly, the frequency of fly landings, and the speed of the fly avoidance behaviors studied precluded the use of video recording. Observations were conducted at three times during the day to allow for known times of day effects (Phipps et al., 1995). Behavior was not sampled more intensively due to personal constraints and the study design.

Fly counts were numerous at both locations in this study, as we expected. This was particularly true by the afternoon counts. The significantly greater fly numbers on the calves with docked tails support the need for the tail at least through the period the calf is in the hutch. Flies can be controlled somewhat by spraying the hutches and frequent cleaning, but during the height of fly season flies are difficult to control in the hutch environment. Most older heifers are either pastured or raised in feed lot situations, but the effect of no tail on fly avoidance responses has not been assessed for this age of dairy heifer in the United States. However, flies become an economic liability because of disruption and alterations of eating patterns and increased energy expenditure in avoidance behaviors. Several studies have demonstrated that biting flies are linked to disrupted grazing and slower growth (Campbell and Berry, 1989), reduced milk production and weight gain and increased stress (Jonsson and Mayer, 1999). Jonsson and Mayer (1999) examined available literature to predict a lower threshold number of flies (n = 30) where adverse effects on milk yield or weight gain could be detected. It could be postulated from our data that without tails, calves would fall into the category above the threshold sooner and remain there longer resulting in decreased gain and greater fly annoyance.

It was surprising to find that tail swings were greater for control calves at both afternoon observations. This raises the possibility of learned helplessness (Ukai, M., 2000; Ronan et al., 2000). Learned helplessness is the lack of behavioral responses seen in animals after being exposed to inescapable aversive stimulus. The calves having not experienced a benefit of tail swings, may have quit trying to use the tail. In contrast, the mature heifers that had used their tails for 2 yr continued to try to use the tail to dislodge flies (Phipps et al., 1995; Eicher et al., 2001).

An interesting phenomenon was the use of licking, subjectively seen as a final effort to alleviate the fly annoyance. This behavior was increased in the docked calves, so was probably a behavior that replaced the use of the tail. Foot stomps and skin twitching were not different between treatments. The foot stomp counts were predictably affected by the increased lying time of the docked calves. Skin twitching is similar between treatments probably because it is useful to dislodge flies from areas that would not be moved by tail swings.

CONCLUSIONS

Increased acute phase protein concentrations were absent in the docked calves, indicating that severe or chronic tissue trauma caused by docking is less frequent in calves than in cows. This research also showed, however, that tail-docking by banding at the age of 3 wk during fly season temporarily reduced calf well-being. This reduction in well-being was indicated by behavioral indicators of pain in young calves at banding and increased flies on the rear of docked calves. Additionally, these data demonstrated the need for tails for fly avoidance in hutches during the height of fly season.

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REFERENCES

Alsemgeest, S. P., M. A. Taverne, R. Boosman, B. C. vander Weyden, and E. Gruys. 1993. Peripartum acute-phase protein serum amyloid-A concentration in plasma of cows and fetuses. Am. J. Vet. Res. 54:164–167.

Anand, K. J. S., V. Coskun, K. V. Thrivikraman, C. B. Nemeroff, and P. M. Plotksy. 1999. Long-term behavioral effects of repetitive pain in neonatal rat pups. Physiol. Behav. 66:627–637.

Baumann, H., and J. Gauldie. 1994. The acute phase response. Immunol. Today 15:74–80.

Bicknell, H. R. Jr., and J. A. Beal. 1984. Axonal and dendritic development of substantia gelatinosa neurons in the lumbosacral spinal cord of the rat. J. Comp. Neurol. 226:508–522.

Boucher, T., E. Jennings, and M. Fitzgerald. 1998. The onset of diffuse noxious inhibitory controls in postnatal rat pups: a C-Fos study. Neurosci. Lett. 257:9–12.

Campbell, J. B., and I. L. Berry. 1989 Economic threshold for stable flies on confined livestock. Misc. Publ. Entomol. Soc. Am. No. 74:13–22.

Dougherty, C. T., F. W. Knapp, P. B. Burrus, D. C. Willis, and P. L. Cornelius. 1995. Behavior of grazing cattle exposed to small populations of stable flies (Stomoxys calcitrans L.). Appl. Anim. Behav. Sci. 42:231–248.

Eicher, S. D., J. L. Morrow-Tesch, J. L. Albright, J. W. Dailey, C. R. Young, and L. H. Stanker. 2000. Tail-docking influences on behavioral, immunological and endocrine responses in dairy heifers. J. Dairy Sci.83:1456–1462.

Eicher, S. D., J. L. Morrow-Tesch, J. L. Albright, and R. E. Williams. 2001. Tail-docking alters fly number, fly-avoidance behaviors, and cleanliness, but not physiological measures. J. Dairy Sci. 84:1822–1828.

Fender, C., M. Fujinaga, and M. Maze. 2000. Strain differences in the antinociceptive effect of nitrous oxide on the tail flick test in rats. Anesth. Analg. 90:195–199.

Gabay, C., B. Genin, G. Mentha, P. B. Iynedjian, P. Roux-Lombard, and P.Z. Guerne. 1995. Il-1 receptor antagonist (IL-1Ra) does not inhibit the production of C-reactive protein or serum amyloid A protein by human primary hepatocytes. Differentail regulation in normal and tumour cells. Clin. Exp. Immunol. 100:306–313.

Grondahl-Nielsen, C., H. B. Simonsen, J. D. Lund, and M. Hesselholt. 1999. Behavioural, endocrine and cardiac responses in young calves undergoing dehorning without and with use of sedation and analgesia. Vet. J. 158:14–20.

Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching, 1st rev. ed. 1999. Consortium, Federation of Animal Science Societies, Association Headquarters, 1111 N. Dunlop Avenue, Savoy, IL. 61874.

Guy, E. R., and F. V. Abbott. 1992. The behavioral response to formalin in preweaning rats. Pain 51:81–90.

Jonsson, N. N., and D. G. Mayer. 1999. Estimation of the effects of buffalo fly (Haematobia irritans exigua) on the milk production of dairy cattle based on a meta-analysis of literature data. Med. Vet. Entomol. 13:372–376.

Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS System for Mixed Models, SAS Inst. Inc., Cary, NC.

Matthews, L. R., A. Phipps, G. A. Verkerk, D. Hart, J. N. Crockford, J. F. Carragher, and R. G. Harcourt. 1995. The effects of tail docking and trimming on milker comfort and dairy cattle health, welfare and production. Pages 1–25 in Animal Behaviour and Welfare Res. Center Rep., MAF, Wellington, NZ.

McNeal, C. D., Jr., and J. B. Campbell. 1981. Insect pest management in Nebraska feedlots and dairies: a pilot integrated pest management project. Page 43 in Dept. Entomol. Rep. #10, Univ. of Nebraska, Lincoln.

Morimatsu M., B. Syuto, N. Shimada, T. Fujinaga, S. Yamamoto, M. Saito, and M. Naiki. 1992. Isolation and characterization of bovine haptoglobin from acute phase sera. J. Biol. Chem. 266:11833–11837.

Narsinghani, U. and K. J. S. Anand. 2000. Developmental neurobiology of pain in neonatal rats. Lab. Anim. 29:27–39.

Petrie, N. J., D. J. Mellor, K. J. Stafford, R. A. Bruce, and R. N. Ward. 1996. Cortisol responses of calves to two methods of tail docking used with or without local anaesthetic. N.Z. Vet. J. 44:4–8.

Phipps, A. M., L. R. Matthews, and G. A. Verkerk. 1995. Tail docked dairy cattle: fly induced behaviour and adrenal responsiveness to ACTH. Proc. N.Z. Soc. Anim. Prod. 55:61–63.

Ren, K., E. M. Blass, Q. Zhou, and R. Dubner. 1997. Suckling and sucrose ingestion suppress persistent hyperalgesia and spinal Fos expression after forepaw inflammation in infant rats. Proc. Natl. Acad. Sci. 94:1471–1475.

Ronan, P. J., M. Steciuk, G. L. Kramer, M. Kram, and F. Petty. 2000. Increased septal 5-HIAA efflux in rats that do not develop learned helplessness after inescapable stress. J. Neurosci. Res. 61:101–106.

SAS User's Guide: Statistics, Version 8.1 Edition. 2000. SAS Inst., Inc., Cary, NC.

Schwinghammer, K. A., F. W. Knapp, and J. A. Boling. 1987. Physiological and nutritional response of beef steers to combined infestations of horn fly and stable fly (Diptera: Muscidae). J. Econ. Entomol. 80:120–125.

Sylvester, S. P., K. J., Stafford, D. J. Mellor, R. A. Bruce, and R. N. Ward. 1998. Acute cortisol responses of calves to four methods of dehorning by amputation. Aust. Vet. J. 76:123–126.

Taschke, A. C. and D. W. Folsch. 1997. Ethological, physiological and histological aspects of pain and stress in cattle when being dehorned. Tierarzliche Praxis 25:19–27.

Tom, E., J. Rushen, I. J. H. Duncan, and A. M. B. de Passille. 2001. Acute effects of method of tail docking on young calves. Page 51 in Proc. 35th Internat. Congr. of the ISAE. 2001.

Tucker C. B., D. Fraser, and D. M. Weary. 2001. Tail docking dairy cattle: effects on cow cleanliness and udder health. J. Dairy Sci. 84:84–87.

Ukai, M. Influence of stress on learning and memory. 2000. Nihon Shinkei Seishin Yakurigaku Zasshi 20:93–96.

Wang, J., D. B. Reichling, A. Kyrozis, and A.B. MacDermott. 1994. Developmental loss of GABZ-and glycine-induced depolarization and Ca2+ transients in embryonic rat dorsal horn neurons in culture. Eur. J. Neurosci. 6:1275–1280.

Watts, J. M. and J. M. Stookey. 1999. Effects of restraint and branding on rates and acoustic parameters of vocalization in beef cattle. Appl. Anim. Behav. Sci. 62:125–135.

Wilson, G. D. A. 1972. Docking cows' tails. Pages 158-165 in Ruakura Farmers Conf., Ruakura, N.Z.

Zenor, B. N. 1997. Effects of cannabinoids on serum cortisol, prolactin, growth hormone, respiration rate, and pain perception in calves. M.S. Thesis, Purdue Univ., West Lafayette, IN.